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Infrared Image Edge Detection Based on Morphology-Canny Fusion Algorithm

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Abstract

Effectively extracting the contour edge of the defect in the infrared image can realize the recognition of the geometrical features of the defect. In view of the traditional Canny edge detection algorithm in the Gauss filter variance and high and low threshold selection need artificial intervention, does not have the adaptive ability, and its defects in the gradient calculation, proposed a method based on the improved Canny operator and image morphological fusion edge detection method. Using the improved Canny operator and image morphology to edge detection, the simulation results show that the algorithm has good anti noise ability, effectively improve the accuracy and integrity of the edge detection in the infrared image, and achieve a better extraction of geometric features of the edge of the defect.

Keywords: *Morphology; Canny operator; edge detection; infrared image*

1. Introduction

Edge detection is the basis of image information extraction and pattern recognition, which is an important content in the field of image processing. Image edge detection results directly affect the effect of further image processing, pattern recognition. Effectively extracting the contour edge of the defect in the infrared image can realize the recognition of the geometrical features of the defect. In recent decades, image edge detection technology has become one of the important research topics of digital image processing technology. Edge has important information characteristics, accurate and reliable edge detection method will be helpful for image feature description, image enhancement, image segmentation and pattern recognition and so on. Because of the noise and the edge of the image are high frequency signal, the general method is very difficult to effectively separate the two regions, a good edge detection method is able to filter out the noise while the edge is also to be accurate and clear. So, the accuracy and integrity of edge detection is a direct impact on the selection of the whole image, and the research on it has become one of the hot spots in image analysis and processing technology [1-5].

Traditional image edge detection methods are mostly based on the extraction of high frequency signal. Roberts, Prewitt and Sobel are the commonly used one order operators. The most representative of the edge detection operator based on the two order derivative zero crossing detection is LoG operator, which is presented by Marr and Hildreth [6-10]. These operators are local window gradient operators, the advantage is that the computation is small, but in a certain extent, some edge information is lost, the detection effect is not ideal. The advantage of these operators is in the image without noise can better image edge detection, and the operation is relatively simple, is a very good real-time, but when in the presence of noise, because these operators are sensitive to noise, so it is difficult to distinguish between image noise and edge, the true edge of the part due to

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the interference of noise to be missed, the noise point for the detection of edge points out. At the same time, the edge of the image is blurred, and the edge is not high. So the effect is not ideal in the actual image processing. In 1986, Canny John proposed that the edge detection operator should satisfy three criteria. First, signal to noise ratio criterion; Second, positioning accuracy criteria; Third, single edge response criterion, and the optimal edge detection operator -Canny operator is derived. Compared to the differential operators, the Canny operator based on the optimization algorithm is widely used in the high SNR and high detection accuracy, and has become the standard for evaluating other edge detection methods. But the variance of the Gauss function and the choice of the high and low threshold are all manual setting, and the adaptive ability is poor; moreover, it uses the finite difference mean value of 2×2 neighborhood, and is sensitive to noise[11-12].

Mathematical morphology is a new discipline which is based on image analysis. It can be used to measure and extract the shape of the image in order to realize the image analysis and recognition. It has obvious advantages in solving the problem of removing noise and edge detection. Basic operations include Expansion, corrosion, open operation and close operation.

Due to the continuous improvement of the edge detection algorithm, the integration of various algorithms and algorithms has become a new trend in the current research. The combining mathematical morphology and Canny operator edge extraction method, using morphology open operator to estimate the background, and original image global gray of geometric computing effect to reduce the background complex texture and noise of the image, to extract the defect geometric feature of edges better.

2. Traditional Canny Edge Detection Algorithm and its Defect Analysis

2.1. Gauss Filtering Smooth Image

Before processing the Canny algorithm, the image is smoothed by Gauss smoothing filter to remove the noise, that is to use Gauss smoothing filter and image convolution. The purpose is to eliminate the noise, because the noise in the image corresponds to the high frequency part of the image, so we must try to reduce the frequency components in the frequency domain.

Canny edge detection algorithm is the product of the ratio of signal to noise ratio and the positioning accuracy of the. Canny algorithm is first used to smooth the image of the first derivative of the two-dimensional Gauss function, set the two-dimensional Gauss function as

$$G(x,y) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \tag{1}$$

Its gradient vector is

$$\nabla G = \begin{bmatrix} \partial G/\partial x \\ \partial G/\partial y \end{bmatrix} \tag{2}$$

Improve the speed by using the method of decomposition, the two filter template of ∇G is decomposed into two one-dimensional row filter, whose expression is

$$\partial G/\partial x = kx\exp\left(-x^2/2\sigma^2\right)\exp\left(-y^2/2\sigma^2\right) \tag{3}$$

$$\partial G/\partial y = kx\exp\left(-y^2/2\sigma^2\right)\exp\left(-y^2/2\sigma^2\right) \tag{4}$$

The two one - dimensional filters are respectively with the image $f(x, y)$ convolution, and the output image $I(x, y)$ is obtained.

$$E_x(x, y) = \frac{\partial G}{\partial x} f(x, y) \tag{5}$$

$$I(x, y) = \frac{\partial G}{\partial y} E_x f(x, y) \tag{6}$$

In the formula, k is a constant, σ is the Gauss filter distribution parameters, it determines the width of the Gauss filter, control the degree of smoothness. For σ small filter, although the positioning accuracy is high, but the signal to noise ratio is low; the σ is the opposite.

2.2. Calculate the Amplitude and Direction of the Gradient

In the traditional Canny algorithm, the gradient amplitude and gradient direction of the data array are calculated by the finite difference method with 2×2 neighbors. Partial derivative array $P_x[i, j]$ and $P_y[i, j]$ of the direction of x and y can be written as

$$P_x[i, j] = \left(I[i, j+1] - I[i, j] + I[i+1, j+1] - I[i+1, j]\right)/2 \tag{7}$$

$$P_y[i, j] = \left(I[i, j] - I[i+1, j] + I[i, j+1] - I[i+1, j+1]\right)/2 \tag{8}$$

The gradient amplitude and gradient direction of the pixel are calculated using the rectangular coordinates to polar coordinates, and the gradient amplitude is calculated by using the two order norm.

$$M[i, j] = \sqrt{P_x[i, j]^2 + P_y[i, j]^2} \tag{9}$$

Gradient direction

$$H[i, j] = \arctan\left(P_y[i, j] / P_x[i, j]\right) \tag{10}$$

If the magnitude of the gradient is greater than or equal to the gradient of two adjacent pixels along the gradient direction, the point is likely to be the edge.

2.3. Double Threshold Method for Detecting and Connecting Edges

The dual threshold algorithm is used to segment the image with high and low threshold values, and two threshold edge images $T_1(i, j)$ and $T_2(i, j)$ are obtained by using high and low two threshold values. Since the image $T_1(i, j)$ is obtained by a high threshold, it should not contain false edges, but $T_1(i, j)$ may have discontinuities in the contour. Therefore, the dual threshold algorithm in $T_1(i, j)$ to the edge of the connection into the outline, when the contour endpoint is reached, the algorithm can find the edge connects to the contour located 8- neighborhood location of $T_2(i, j)$.

2.4. Defect Analysis of Canny Algorithm

1) Because the value σ is not automatically determined and need to be set, so the traditional Canny algorithm in extracting the edge of different images, there is a lot of limitations;

2) The traditional Canny algorithm in calculating the gradient amplitude, the use is 2×2 neighborhood of first order partial derivative of the finite difference, make the noise more sensitive, easily lead to false detection.

3) Traditional Canny algorithm in determining the high, low threshold is also a prior to the adoption of human settings. This makes the continuity between the pseudo edge and the edge of the contradiction, the same group of high and low threshold for different images, the edge detection quality is very different.

3. Basic Theory of Mathematical Morphology and Edge Detection Method

Mathematical morphology is a mathematical method, which is based on morphological structure elements to analyze and describe the geometry and structural properties. It is also a kind of nonlinear processing system based on geometric algebra and set theory. The basic idea of mathematical morphology is to measure the effectiveness of the method of the structural elements of a certain shape to measure the effectiveness of the method and the method of filling in the target image. Mathematical morphology can eliminate the morphological and structural properties, which is not related to the target image, while preserving the basic nature of the shape and structure, and achieve the purpose of simplifying the target image data. The most basic morphological operators include corrosion, expansion, open operation and close operation [13-15].

3.1. Morphology Expansion

A new form of structure element B_a, which has a certain form of structural element B shifts distance a, is obtained. If A and B_a are in the same A, the B is expressed as a set of elements that satisfy the condition:

$$D(A) = \{a \mid B_a \cap A\} = A \oplus B \tag{11}$$

3.2. Morphology Erosion

A new form of structure element B_a is obtained by B shifts distance a, which is composed of A, and all the collection of elements that satisfy this condition is called A is eroded by B. The formula is expressed as

$$E(A) = \{a \mid B_a \subseteq A\} = A \ominus B \tag{12}$$

3.3. Open POperation

Using the same structural elements of the image first erosion operation, and then the results of the method of expansion is called open operation, the formula is expressed as

$$A \circ B = (A \ominus B) \oplus B \tag{13}$$

Open operation can smooth the image contour, weaken the narrow part, removing the burr and the isolated spots of the long and thin protruding edges, disconnect between the target and so on, its main effect on corrosion is similar.

3.4. Closed Operation

Using the same structural elements to expand the image first, and then the results of the method of erosion operation is called closed operation, the formula is expressed as

$$A \bullet B = (A \oplus B) \ominus B \tag{14}$$

Close operation can also be smoothed image of the contour. Compared with open operation, closed operation is generally used to fill the small hole and crack in the target. The main function of the connection is similar to the expansion effect, but it is also the same as the size of the target.

3.5. Morphological Edge Detection Operator

The basic idea of the traditional morphological edge detection operator is to do morphological gradient processing of the original image, so that the gray level of the input image is more acute, and then the image edge is detected. With the help of the basic operations of all kinds of morphological operations, the morphological gradient MG is usually expressed in the following forms:

$$\begin{aligned} MG_1(A) &= (A \oplus B) - A \\ MG_2(A) &= A - (A \ominus B) \\ MG_3(A) &= (A \oplus B) - (A \ominus B) \\ MG_4(A) &= \min\{[(A \oplus B) - A], [A - (A \ominus B)]\} \end{aligned} \tag{15}$$

4. Edge Detection Method Based on Image Fusion

In this paper, the image fusion based edge detection algorithm flow is shown in Figure 1, the specific implementation process is as follows

(1) Edge detection using Canny operator:

①The image smoothing is carried out using the adaptive median filter with 3×3 windows;

②The amplitude and direction of the gradient is calculated by using the improved 8-neighborhood gradient magnitude method;

③On the gradient magnitude using non maximal suppression;

④Double threshold algorithm is used to detect and connect edges.

(2) A morphological edge detection operator formula (15) is used for edge detection, and the structural element is a circular disc with a radius of 3.

(3) The image fusion technique is applied to the two images of the edge of the Canny, and the image is obtained by the edge fusion.

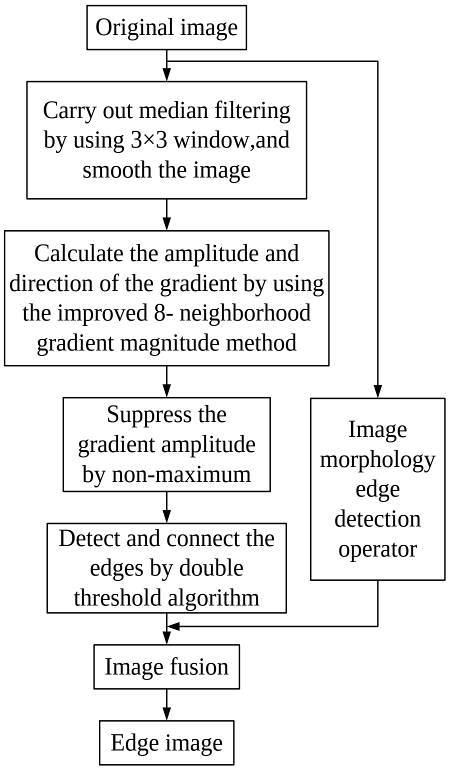

Image Fusion Algorithm Flow Chart

5. Experiment and Analysis

In this paper, the defects edge of infrared thermal image is extracted. Figure 1 shows a thermal image captured by an infrared camera SC7000. Figure 2 shows the image after gray level transformation. Figure 3 shows the edge detection result by Canny operator. Figure 4 shows the image segmentation result by morphology algorithm, after which carried out edge extraction by Canny operator, and the result is shown in Figure 5.

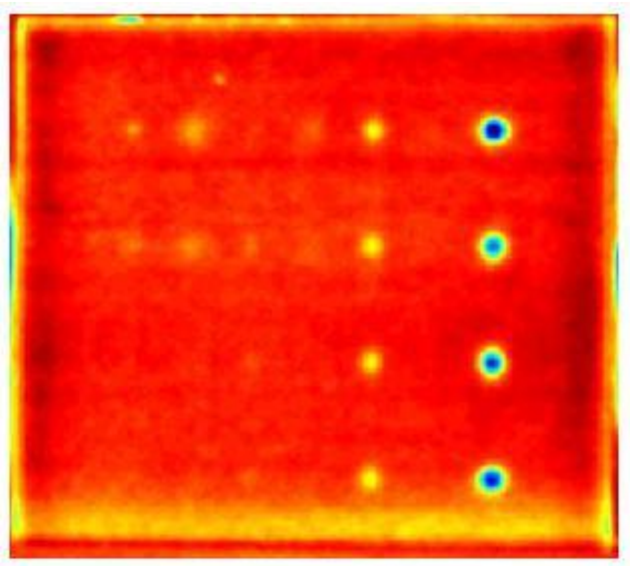

Figure 1. The Input Infrared Image

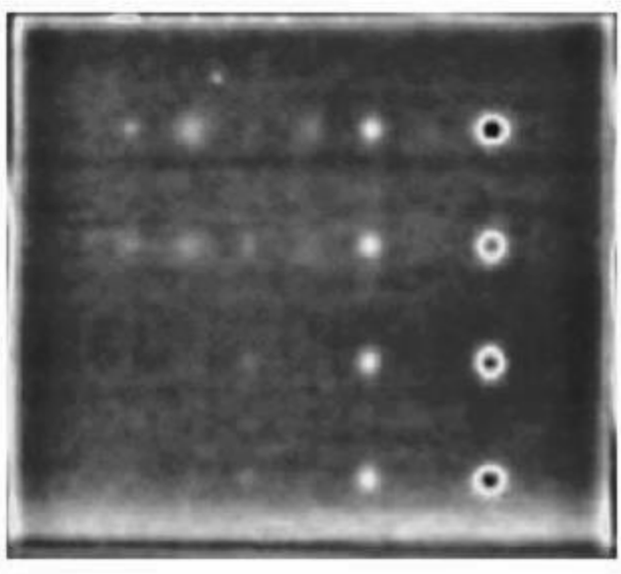

Figure 2. The Input Infrared Image (with Gray Level Transformation)

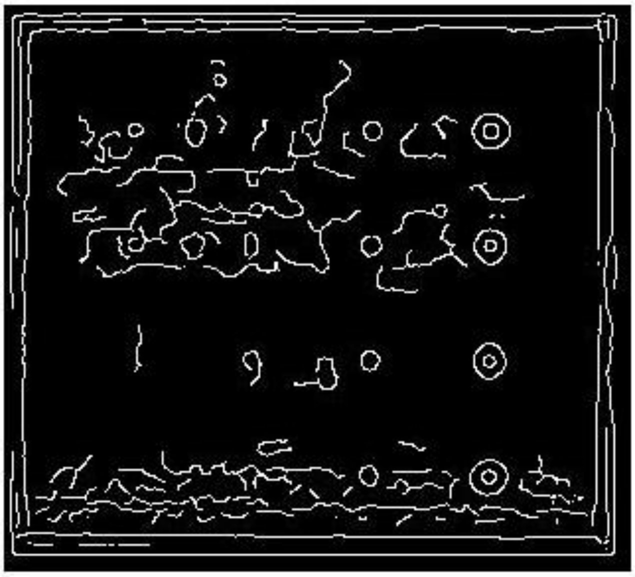

Figure 3. Edge Detection by Canny Operator

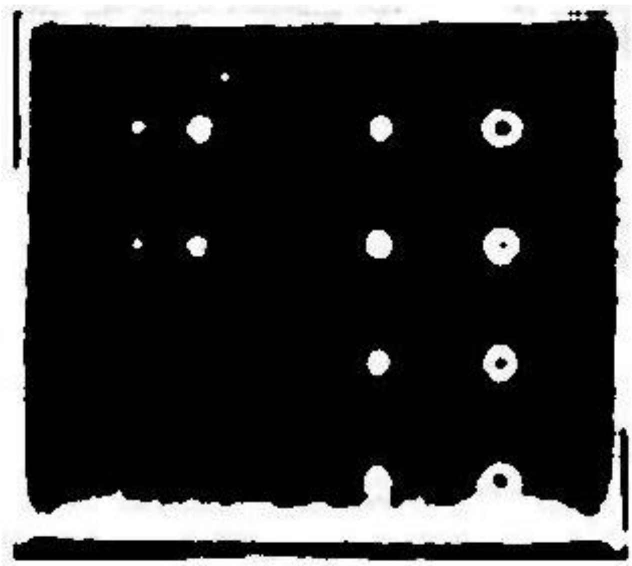

Figure 4. Image Segmentation by Morphology Algorithm

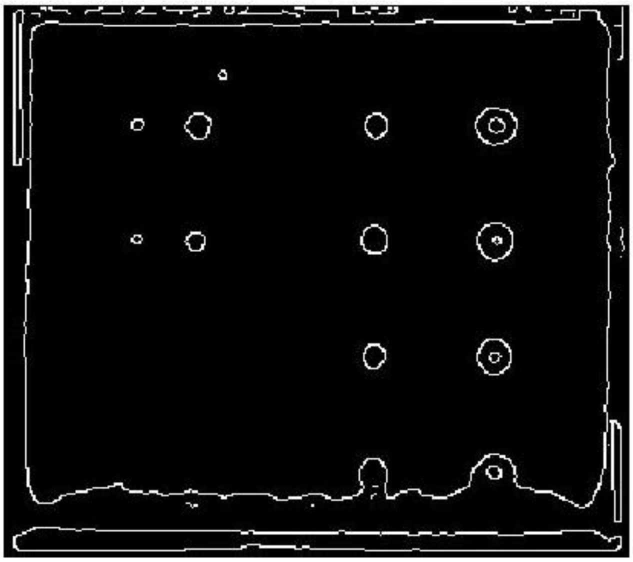

Figure 5. Edge Detection by Morphology - Canny Operator

By comparing Figure 3 and Figure 5, it is known that the traditional Canny operator is sensitive to noise, and the morphology-Canny operator has strong noise suppression ability, and the Canny operator has a clear and coherent edge, which can improve the performance of smooth noise and suppress false edges. And the morphology-Canny operator fusion algorithm enriches the local edge details.

6. Conclusion

In this paper, we identify the edge of infrared image based on morphology-Canny operator. The simulation experiments show that the proposed algorithm can detect the edge details and more complete contour information, improve the accuracy and accuracy of edge detection, which is a valid edge detection method.

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